ETL/PMEL PACS PROGRAM
Enhancements for the Spring and Fall TAO Maintenance Cruises

A modest ship-based cloud measurement program to obtain statistics on key surface, MBL, and low-cloud macrophysical, microphysical, and radiative properties as part of the PACS/EPIC monitoring program for the 95 W TAO buoy line in the tropical eastern Pacific

Goal: to acquire a good sample of most of the relevant bulk variables that are commonly used in GCM parameterizations and to improve satellite retrieval methods for deducing MBL and cloud properties on larger spatial and temporal scales.

Completed: Seven cruises since 1999 (plus the EPIC2001 cruise)

Cronin, M. F., N. Bond, C. W. Fairall, J. E. Hare, M. J. McPhaden, and R. A. Weller, 2002: Enhanced oceanic and atmospheric monitoring for the Eastern Pacific Investigation of Climate Processes (EPIC) experiment. *EOS, Transactions of AGU*, **83**, 205-211.

*Buoys are REFERENCE sites. *High-resolution data*:

More accurate, more detailed, more fundamental
Shows **why** buoys get the fluxes they get.

Example: Buoy data show NCEP suppose overestimates downward solar flux by 100 W/m^2 in spring but not in fall. Ship data gives us cloud fraction, cloud optical depth, clear sky solar flux, aerosol optical depth, PBL height

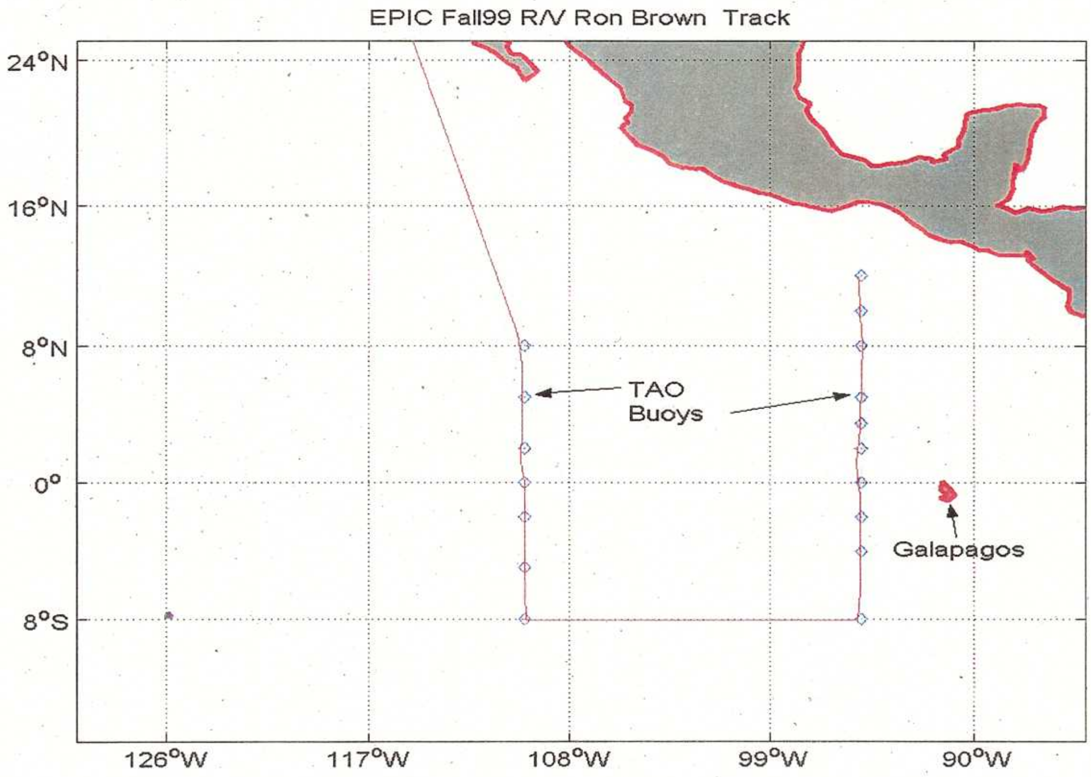
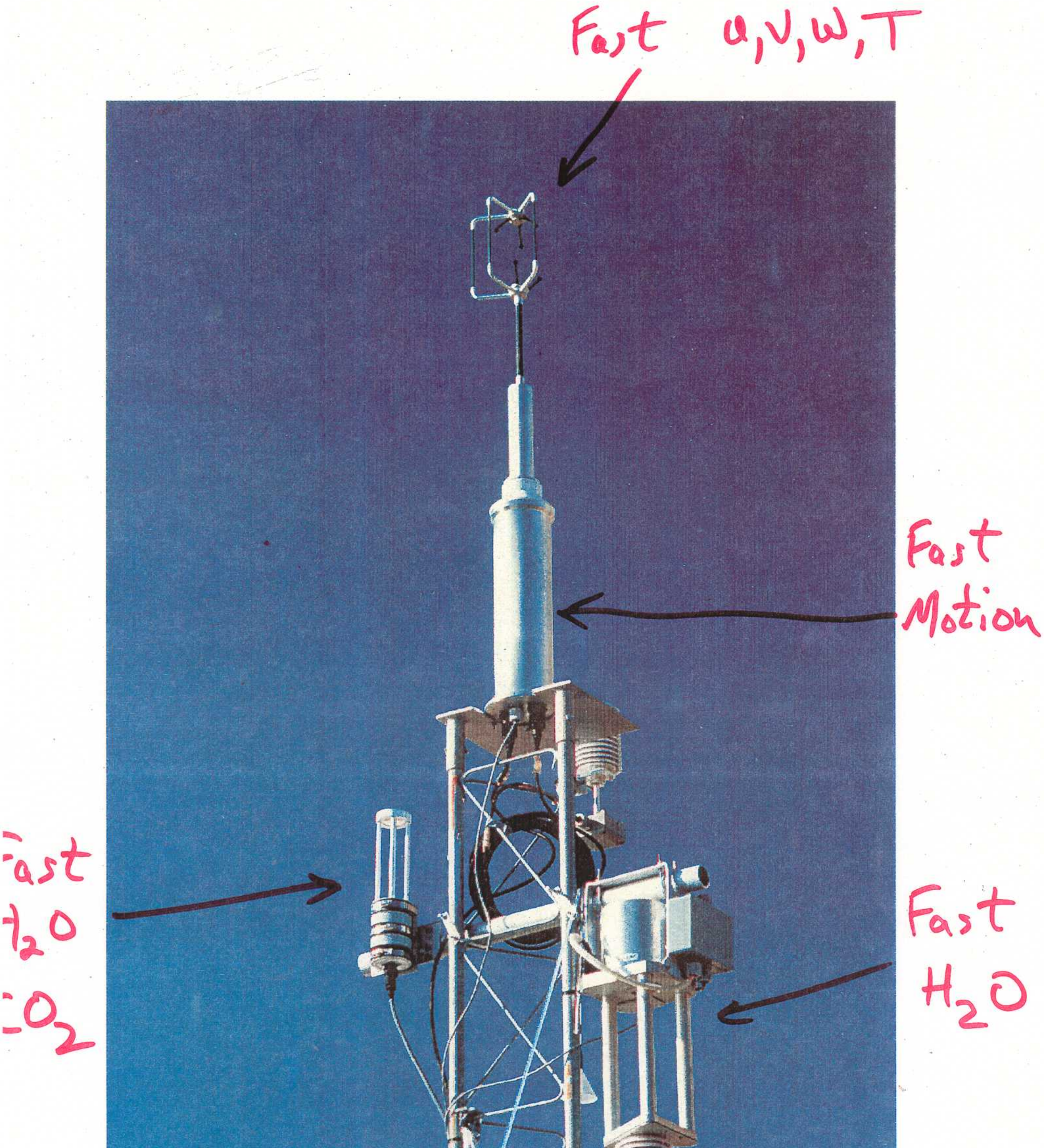
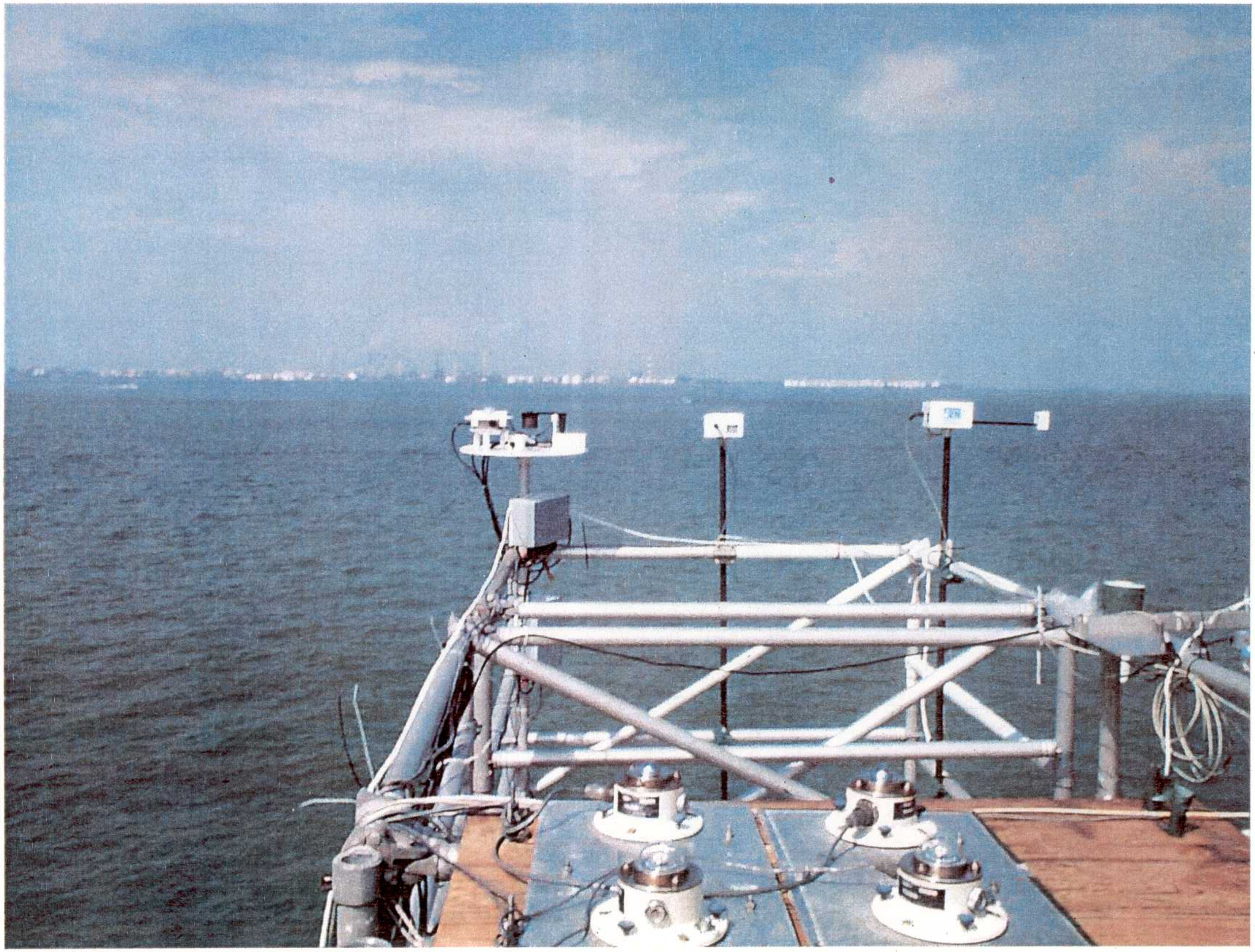


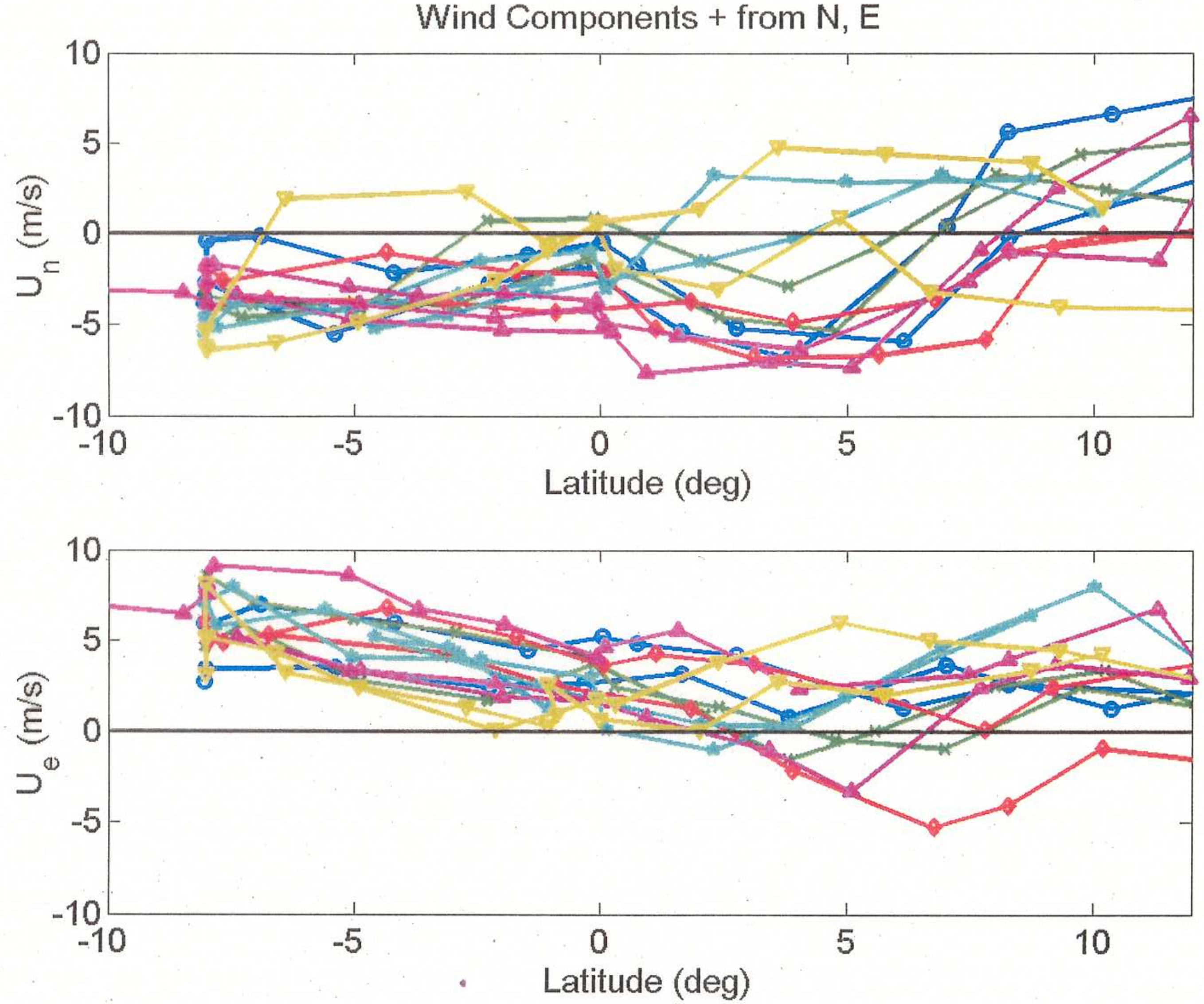
Table 1-1. Present processed data availability at the ETL PACS ftp site: D - data available on this site, I - image files only, X - available but not posted.							
Mission	Flux	Radar profiler	Ceilom.	MWR	Sonde	Cloud radar	C-band radar
fall99	D	I	D	D	D	NA	X*
sp00	D	X	D	D	D	NA	NA
fall00	D	X	D	D	D	I*	I*
sp01	D	X	D	D	D	NA	NA
fall01	D	X	D	D	D	X	X
sp02	X	X	X	X	X	NA	NA
fall02	X	X	X	X	X	NA	NA

Table 1. Instruments and measurements for ETL ship-based cloud/MBL monitoring.

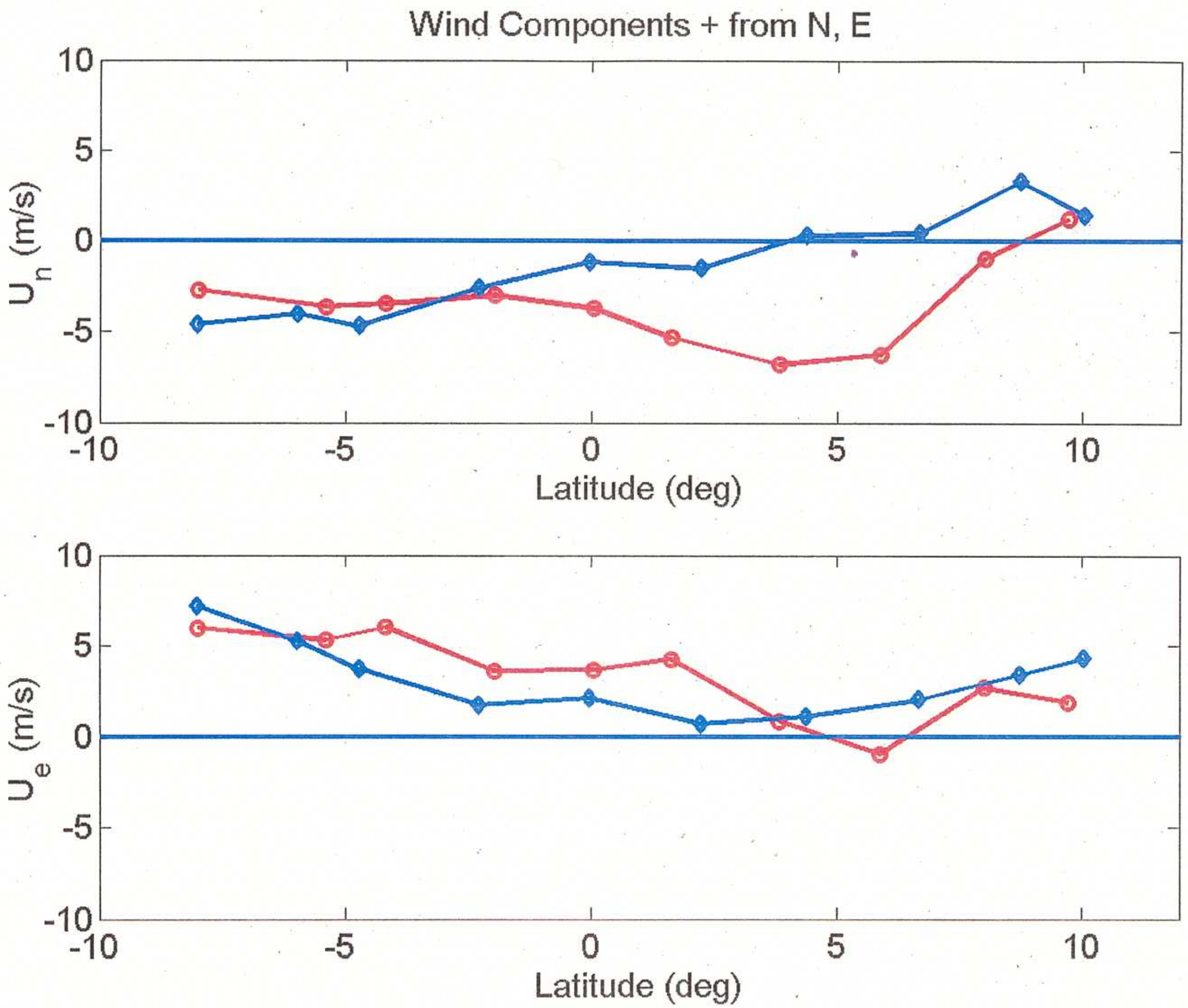
Item	System	Measurement
1	Motion/navigation package	Motion correction for turbulence
2	Sonic anemometer/thermometer	Direct covariance turbulent fluxes
3	Mean SST, air temperature/RH	Bulk turbulent fluxes
4	Pyranometer	Downward solar radiative flux
5	Pyrgeometer	Downward IR radiative flux
6	Ceilometer	Cloud-base height
7	0.92 or 3 GHz Doppler radar profiler	Cloud-top height, MBL microturbulence
8	Rawinsonde	MBL wind, temperature, humidity prof.
9	35 GHz Doppler cloud radar	Cloud microphysical properties
10	20, 31, 90 GHz μwave radiometer	Integrated cloud liquid water
11	Upward pointed IR thermometer	Cloud-base radiative temperature


Fast u, v, w, T
Fast Motion
Fast H_2O
Fast H_2O CO_2





Wind speed components (daily average) versus latitude. Each line denotes a transect along 95 W or 110 W in the fall 1999 to fall 2001 period.



Wind speed components averaged over all cruises versus latitude: Red= fall and blue=spring.

Bulk surface layer properties from deep convective periods in the TWP, Indian Ocean, and TEP.					
Experiment	Ts (C)	Ta (C)	ΔT (C)	Δq (g/kg)	U (m/s)
COR-2	28.98	27.38	1.60	6.45	5.49
JASM Active	29.42	27.94	1.48	6.15	8.71
EPIC ITCZ	29.21	26.64	2.57	6.70	5.26

Bulk surface fluxes from deep convective periods in the TWP, Indian Ocean, and TEP.					
Experiment	Rns	Rnl	Hs	Hl	Hnet
COR-2	166	-46	-11	-117	-12
JASM Active	167	-31	-10.6	-158	-37
EPIC ITCZ	164	-39	-18.9	-122	-22
PACS 10 N	222	-46	-7.7	-88	

Simple Cloud Properties

Simple bulk models of downward IR and solar radiative fluxes have been used for surface cloud radiative forcing on 1-day averages.

$R_{s\downarrow clear}$ = F(lat, lon, day, hour, k_1, k_2, ozone) [Iqbal 1998]

ozone = default; k adjusted to fit clear sky periods

$R_{l\downarrow clear} = \sigma T_a^4 [0.52 + 0.085 (q_a)^{1/2}]$ T_a = air Temp, q_a = spec. hum.

The coefficients (0.52 and 0.085) were selected to fit known clear sky periods.

Cloud forcing of fluxes at the surface:

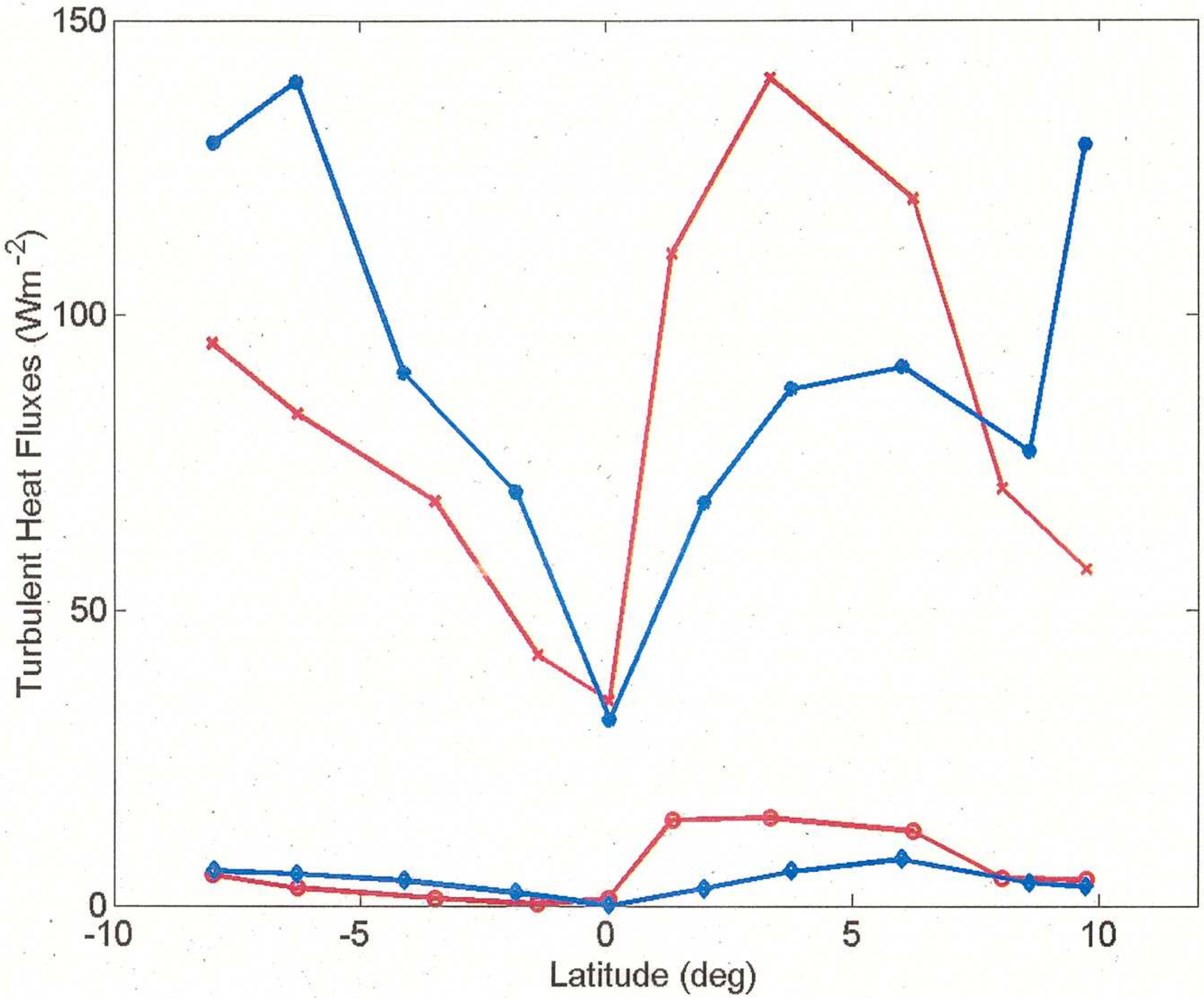
$SCF = \langle R_n \rangle - R_{n\ clear}$

Maximum cloud forcing:

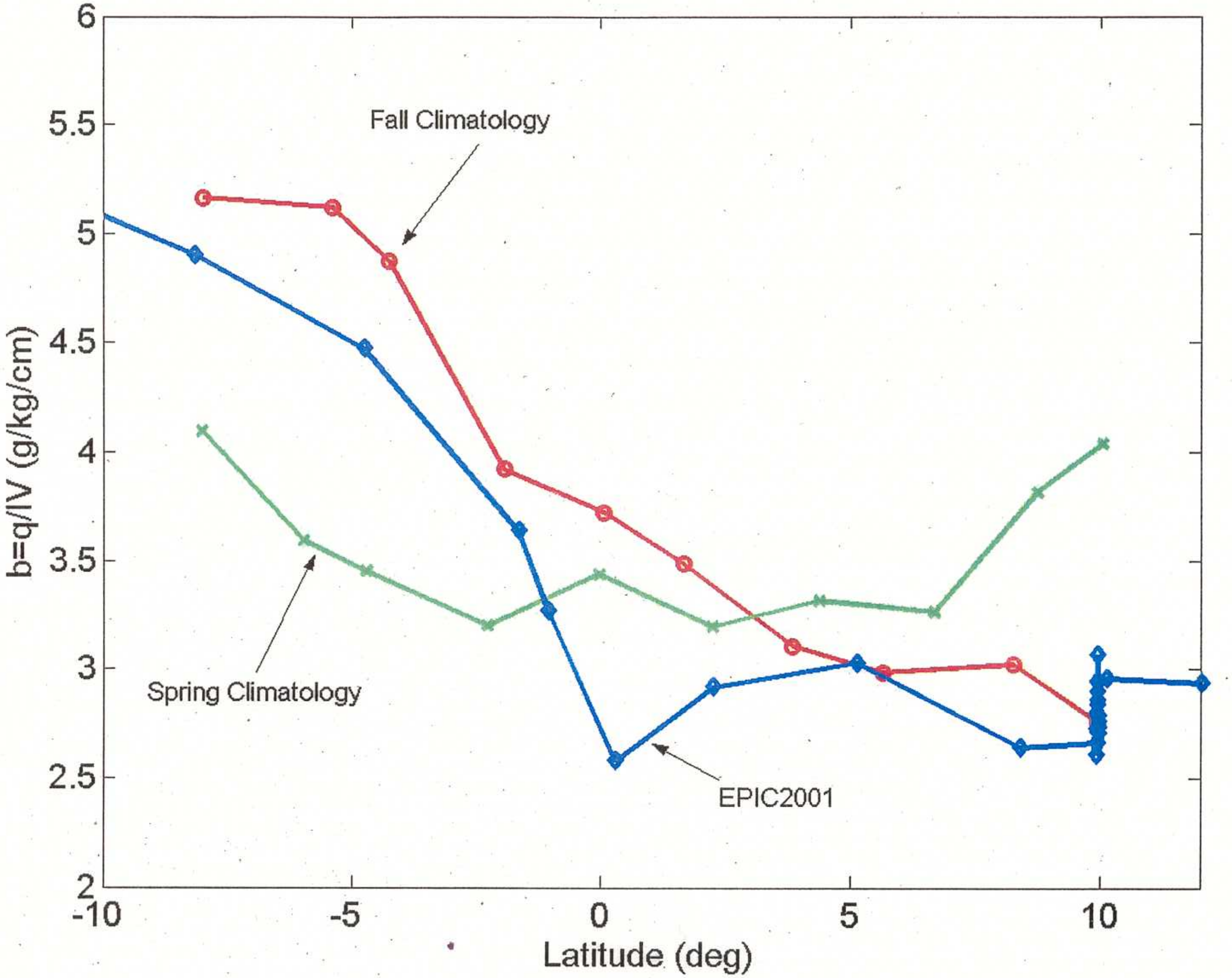
$MSCF = R_{n\ f=1} - R_{n\ clear}$

$SCF \approx f * MSCF$

where f=cloud fraction



Latitude-bin averages of daily-averaged turbulent fluxes: sensible - red circles, fall and blue diamonds, spring; latent - red x, fall and blue *, spring.



Latitude-bin averaged ratio of BL humidity to column precipitable water - red circles, fall and green x's, spring; blue = daily averaged EP2001.

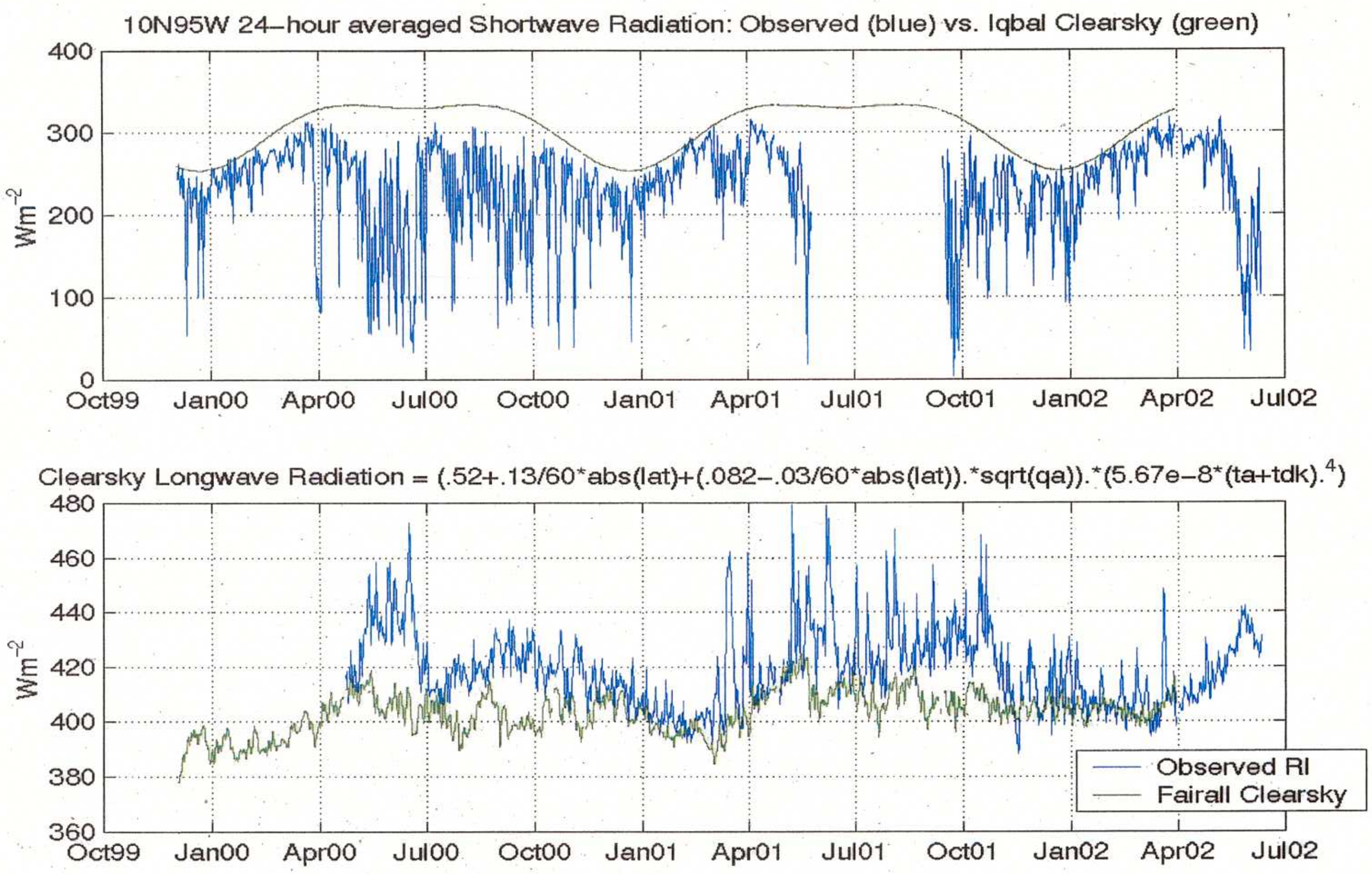


Figure 3. Daily averaged downward solar (upper panel) and IR (lower panel) flux time series for 10 N 95 W. The blue lines are TAO buoy data; the green line clear sky model values based on ETL PACS cruise information. The difference in the two lines is the cloud radiative forcing at the surface. Strong forcing in the May-October period is caused by migration of the ITCZ to 10 N.

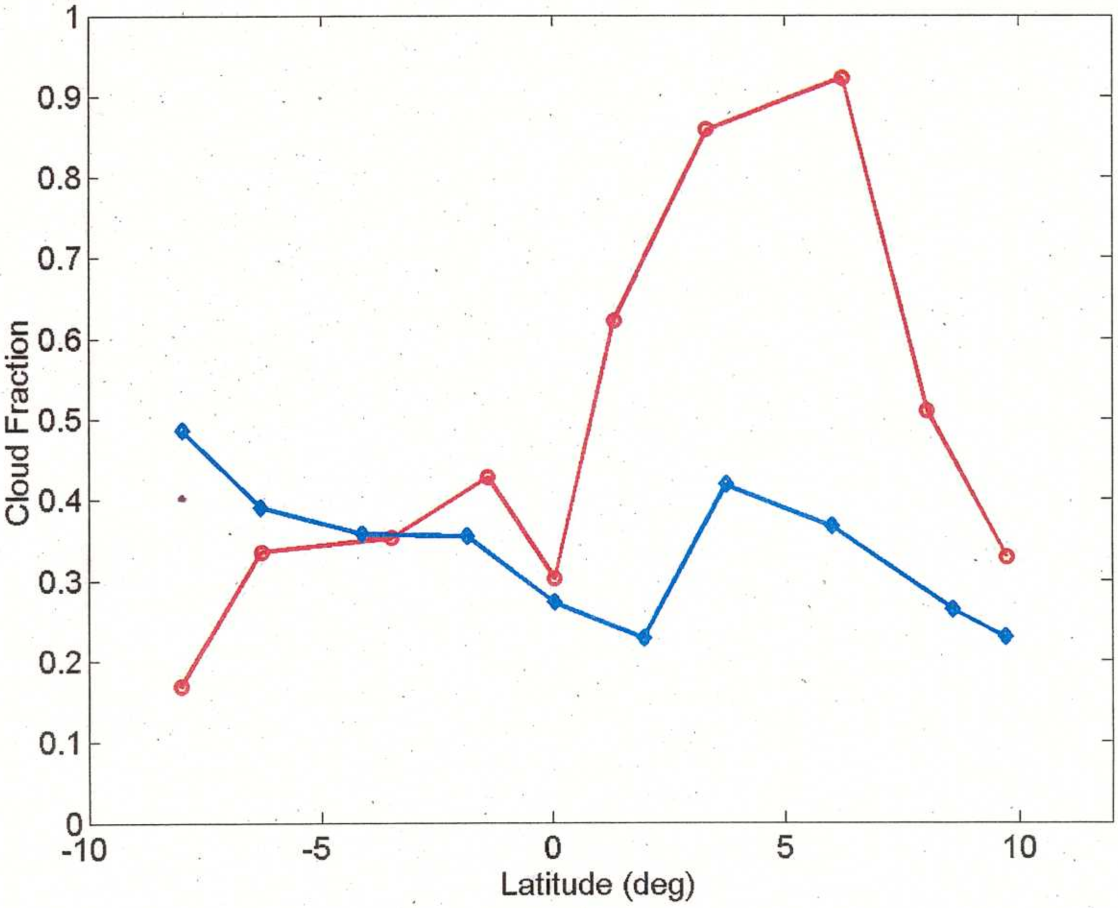
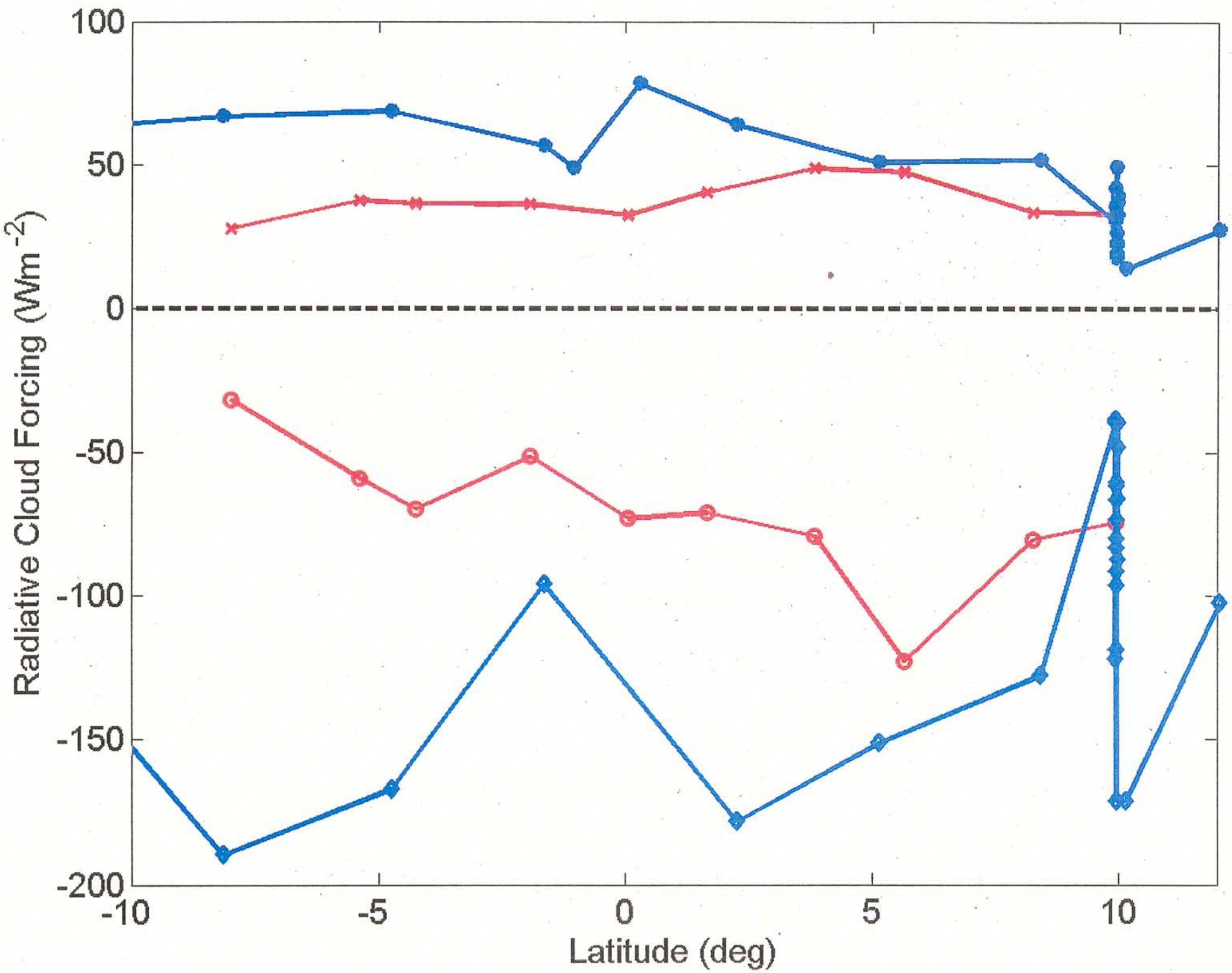
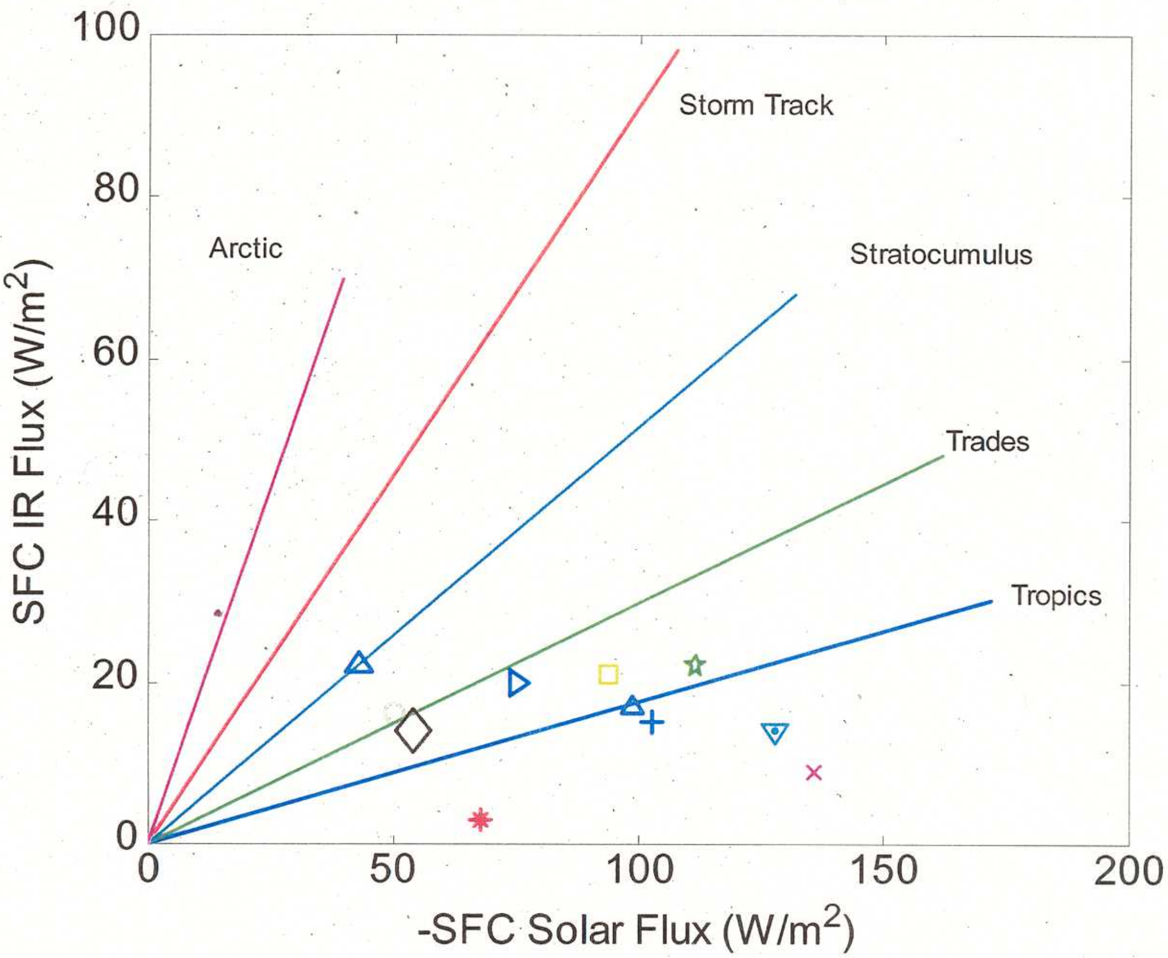


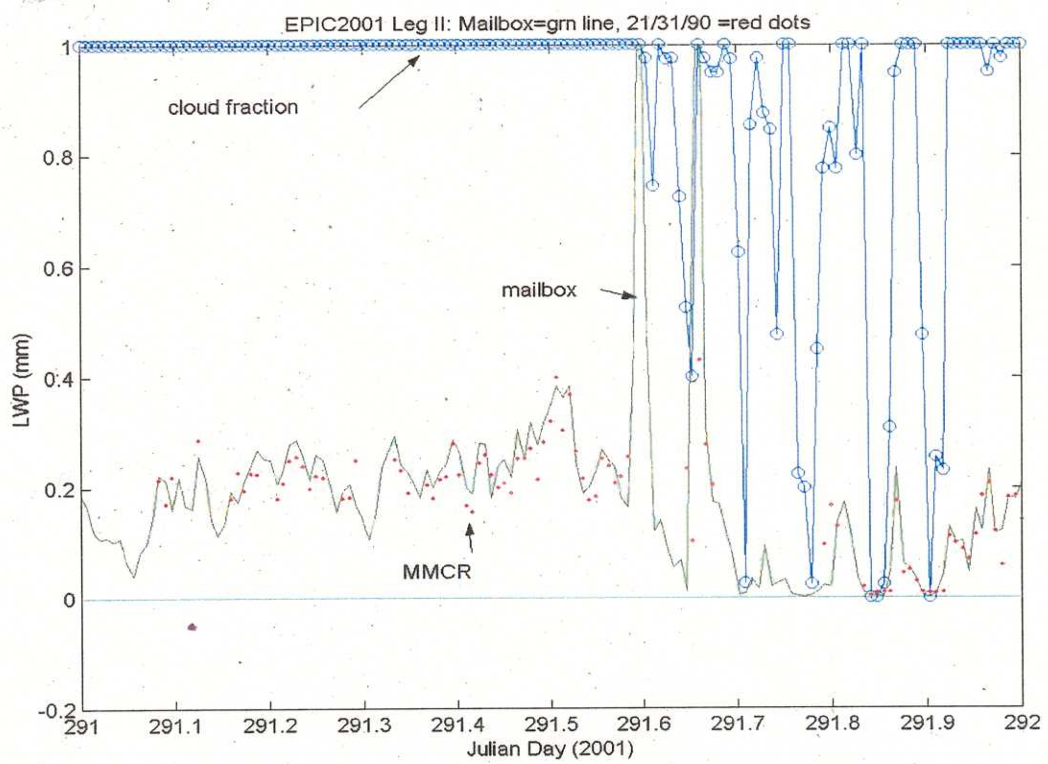
Figure 1. Bin-averaged measurements of low-cloud fraction. Red circles for are fall and blue diamonds are spring.

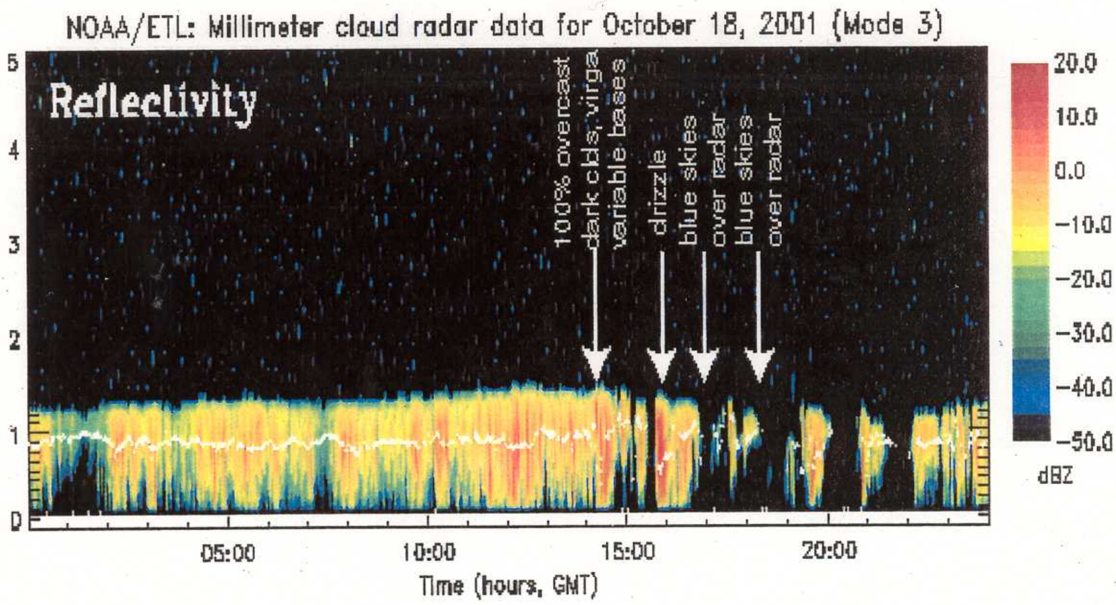


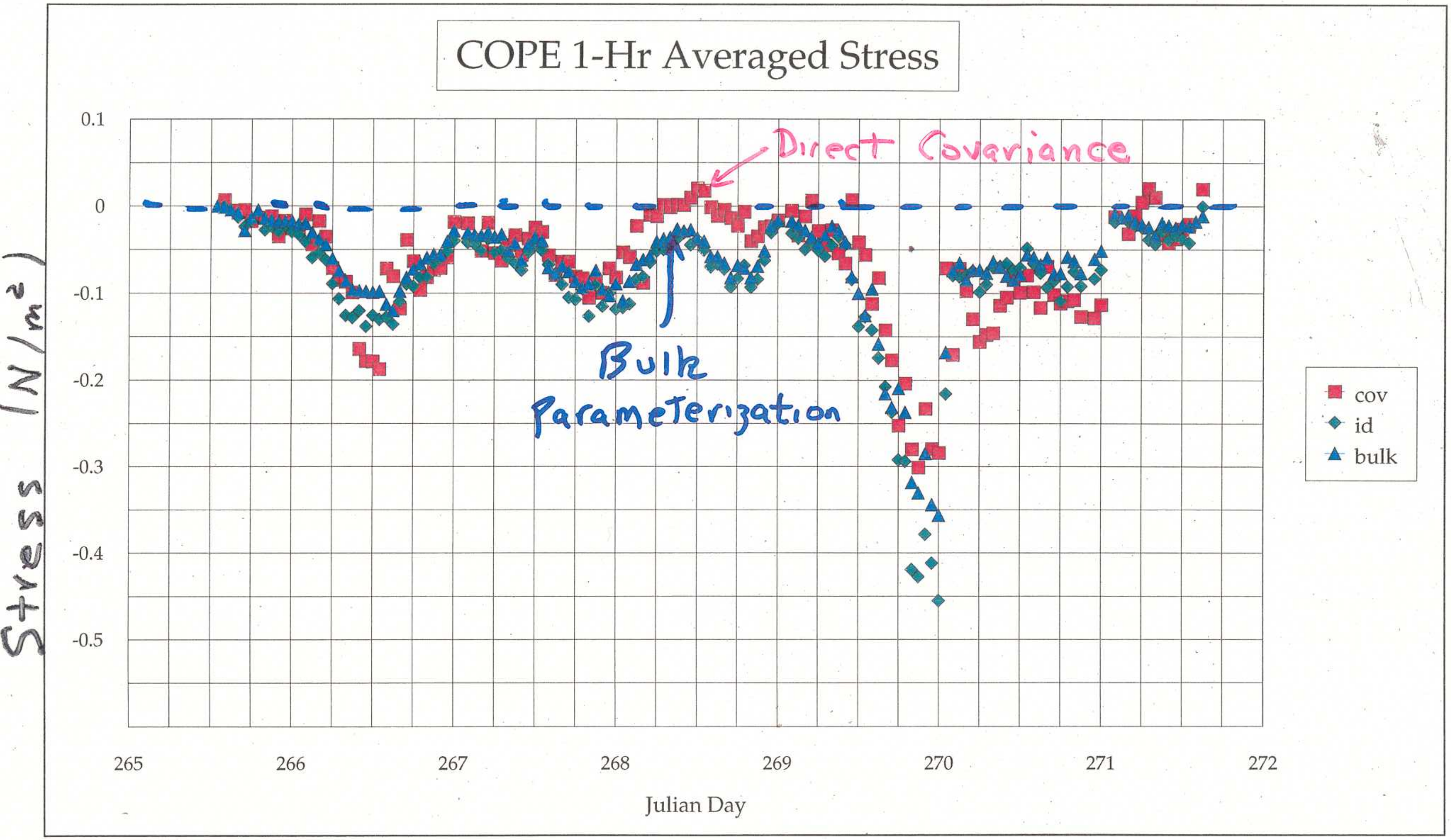
Latitude-bin medians of daily-averaged radiative cloud forcing: red circles, average fall and blue diamonds, EP2001. The upper panel is IR flux and lower is solar flux.



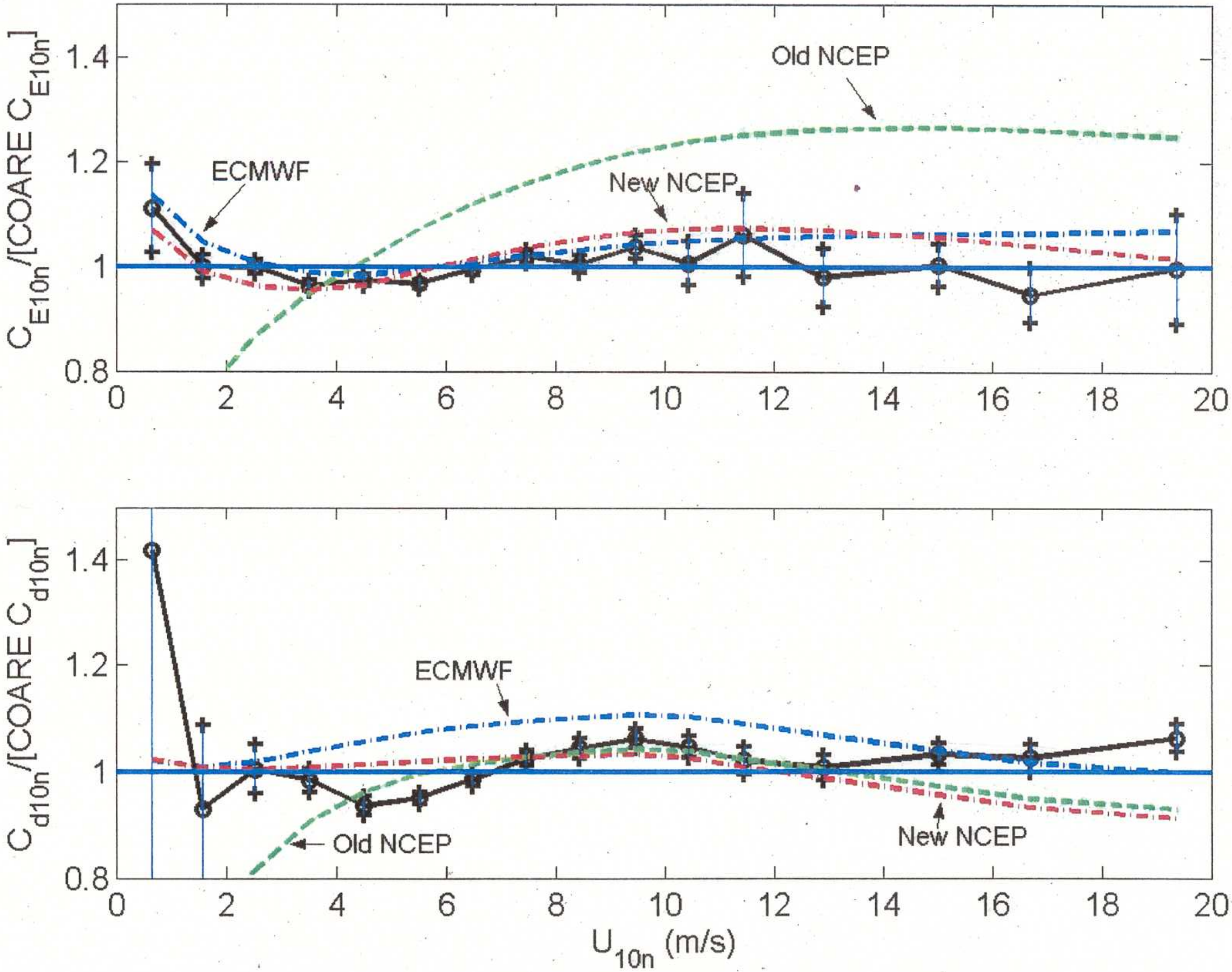
100
80
60
40
20
0
0
50
100
150
200
SFC IR Flux (W/m2)
-SFC Solar Flux (W/m2)
Storm Track
Arctic
Stratocumulus
Trades
Tropics


EPIC2001 Leg II: Mailbox=grn line, 21/31/90 =red dots
cloud fraction
mailbox
MMCR
LWP (mm)
Julian Day (2001)
1
0.8
0.6
0.4
0.2
0
-0.2
291
291.1
291.2
291.3
291.4
291.5
291.6
291.7
291.8
291.9
292


NOAA/ETL: Millimeter cloud radar data for October 18, 2001 (Mode 3)
Reflectivity
100% overcast
dark clds, virga
variable bases
drizzle
blue skies
over radar
blue skies
over radar
5
4
3
2
1
0
05:00
10:00
15:00
20:00
Time (hours, GMT)
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
dBZ



COPE 1-Hr Averaged Stress
Direct Covariance
Bulk Parameterization
Stress (N/m²)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
265
266
267
268
269
270
271
272
Julian Day
cov
id
bulk

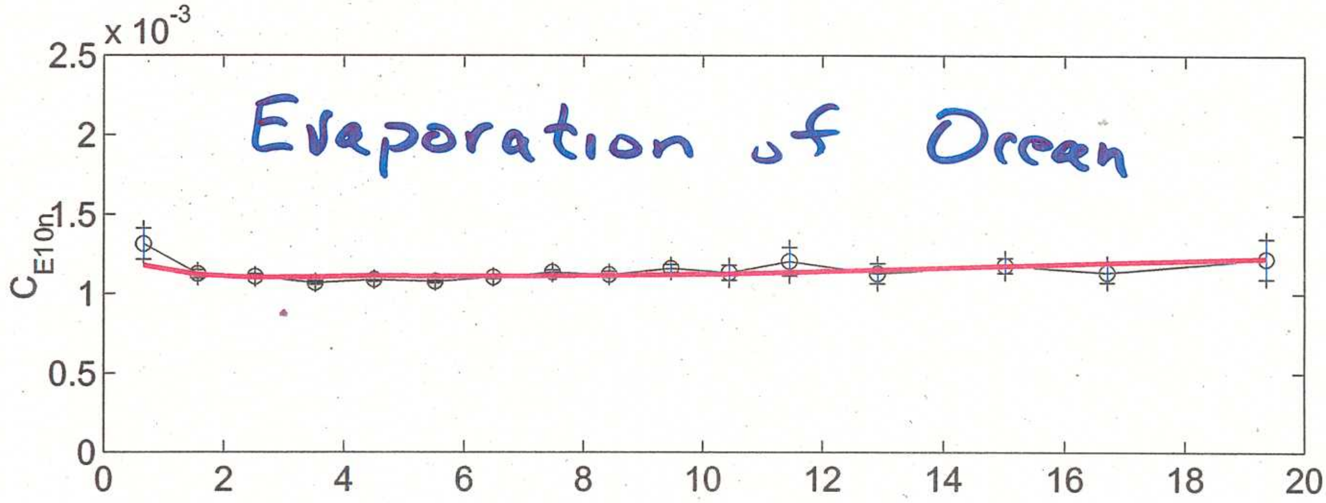


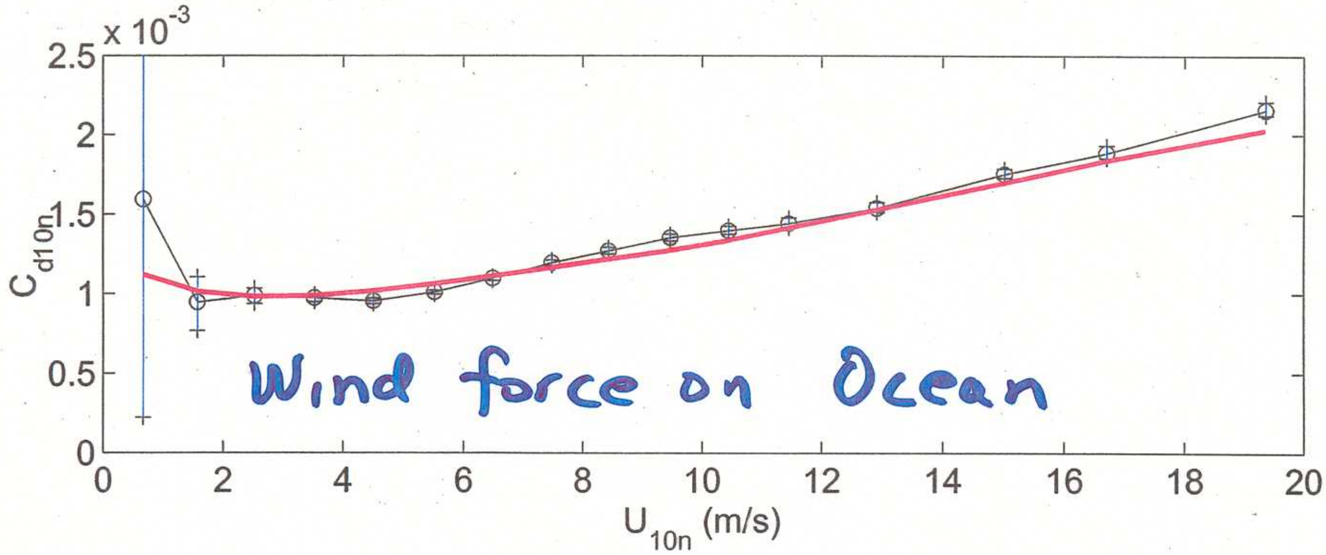
Old NCEP
ECMWF
New NCEP
1.4
1.2
1
0.8
0
2
4
6
8
10
12
14
16
18
20
C_{E10n}/[COARE C_{E10n}]
ECMWF
Old NCEP
New NCEP
C_{d10n}/[COARE C_{d10n}]
U_{10n} (m/s)

FLUX PARAMETERIZATION

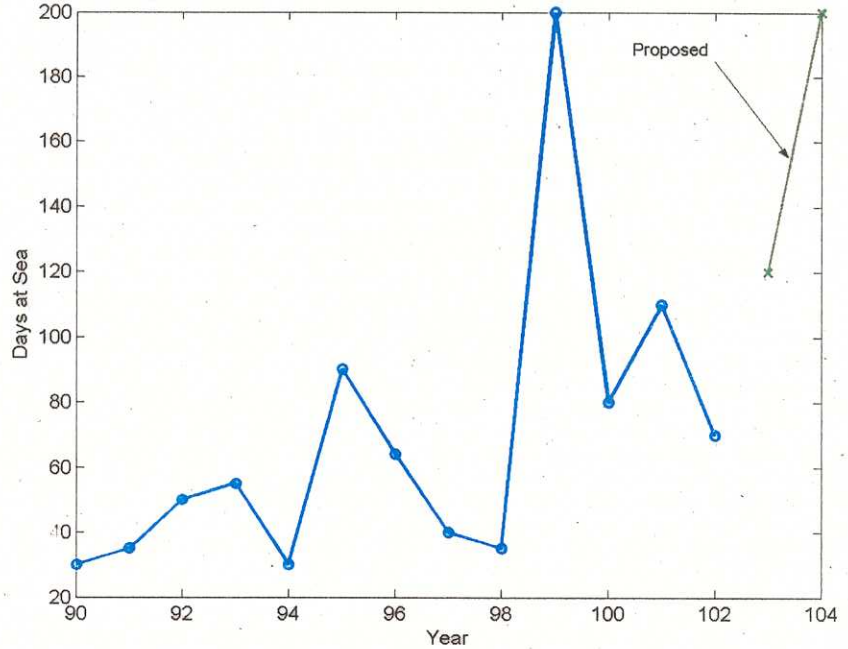
Red Line – ETL flux model

Points – 12 ETL Open Ocean Cruises

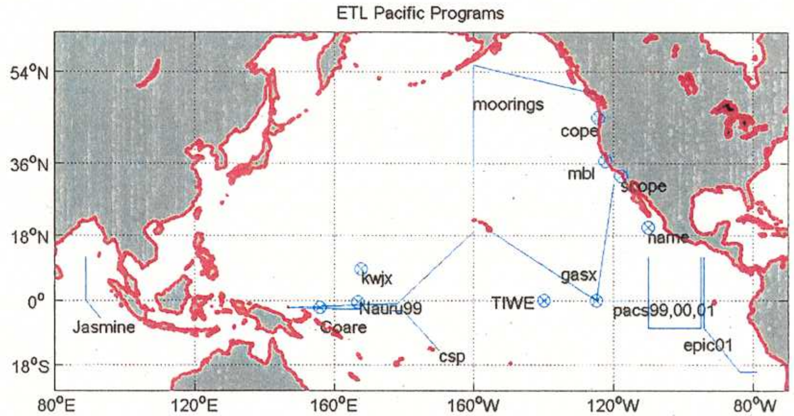


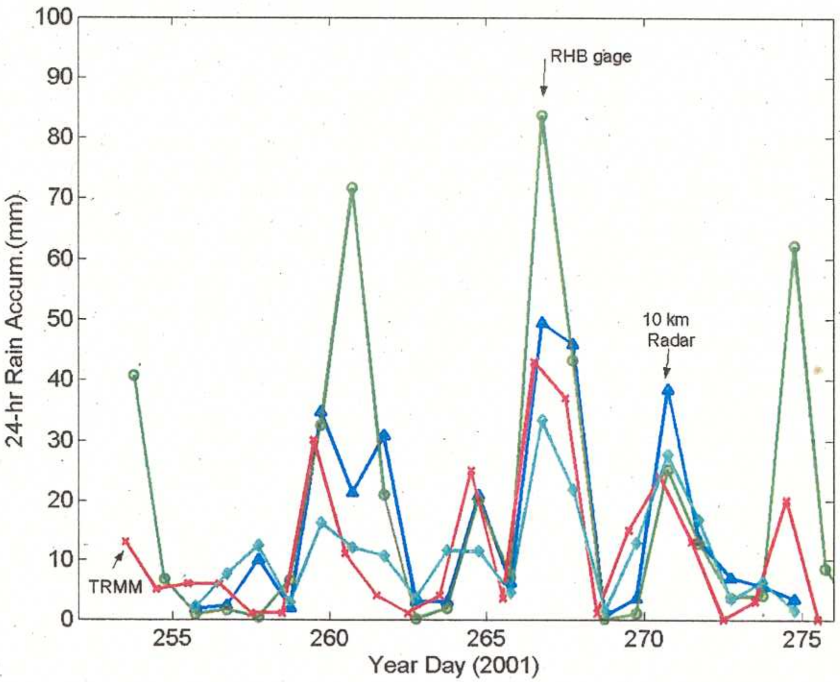


Flux = C Wind Speed [Ocean - Air]


Days at Sea
Year
Proposed
200
180
160
140
120
100
80
60
20
90
92
94
96
98
100
102
104


NOAA


ETL Pacific Programs
moorings
cope
mbl
scope
name
kwjx
Nauru99
Coare
csp
TIWE
gasx
pacs99,00,01
epic01
Jasmine
54°N
36°N
18°N
0°
18°S
80°E
120°E
160°E
160°W
120°W
80°W


24-hr Rain Accum.(mm)
Year Day (2001)
RHB gage
10 km
Radar
TRMM
100
90
80
70
60
50
40
30
20
10
0
255
260
265
270
275

1980

ACTUAL DIRECT MEASUREMENTS OF EVAPORATION OVER THE OPEN OCEAN SINCE 1898

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